



Ministry of Transport, Public Works and Water Management

# THE DELTA: rich and robust





## FOREWORD

After the disastrous flood of 1953, the Netherlands invested heavily in the safety and water management of the southwest Delta. The Delta project has been the subject of a great deal of international interest. But this does not mean that the Delta is ‘finished’. The most important challenge for the coming period is to safeguard the natural wealth of the Delta and to restore its robust nature for the future.

This issue has two motivating factors. First, it has been shown that besides having very positive effects on different aspects, such as safety, the Delta project also has some negative effects. The most important of these is the loss of the natural estuary dynamics that are part of the transition area between a river and the sea. Second, climate changes and changes in use will put new requirements on the organisation and management of the area. European directives, such as the Water Framework Directive (Kaderrichtlijn Water) and the Bird and Habitat Directive (Vogel- en Habitatrictlijn), emphasise the need to invest in the Delta challenge.

Which solutions are possible for making and keeping the Delta rich and robust? It will be necessary to combine all our strengths to arrive at the proper measures. As a result, the three Delta provinces and the government have taken a common stance in ‘A view of the Delta’. The provinces have translated this vision into an agenda for an integrated Delta programme

entitled ‘The Power of the Delta’.

We are already working hard on the Delta programme. Additional information on the vision and the Delta programme is available on the website [www.delta-wateren.nl](http://www.delta-wateren.nl). It is also necessary to combine national and international knowledge. A good example is the exchange of knowledge related to the Delta plan for New Orleans.

This booklet is a publication by the Blauwe Delta project. The aim of this project is to provide advice on policy and measures in the Delta. The booklet provides an overview of the genesis of the Delta, problems that occur, expected developments, important issues and solution strategies for the future. With this, the project team wishes to contribute towards the search for measures and stimulate the essential development of knowledge.

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Ministry of Transport, Public Works and Water Management  
**Directorate-General of Public Works and Water Management**  
**Directorate-General for Water Affairs**



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## 1 INTRODUCTION

*The Delta in the southwest of the Netherlands has a rich history. Throughout the centuries, people have been happy to benefit from its natural wealth and strategic location. As a result, agriculture, fishing, trade and shipping flourished. However, the riches also had a price: the continuous battle against the water. Terps, dikes and dams have put their stamp on the area.*

*Thanks primarily to the Delta project, the safety and accessibility of the area has been greatly improved. But this also has a drawback: the original dynamics of the Delta have largely disappeared. Consequently, many of the unique ecological values have disappeared, the water quality has worsened, sand and silt flows are out of balance and the infrastructure requires expensive maintenance. Climate change and an intensification of use have worsened these problems.*

*How can we best respond to these changes and what is required to develop and safeguard the wealth and robustness of the Delta? These are the most important issues for water policy and water management for the coming decades.*

An intense debate has been ongoing since 2000 on the future development of the Delta region. In 2003, the results of this debate were documented in the integrated vision presented in 'A View of the Delta', in which the health, safety and sustainable future of the Delta region is at stake. Three years later, the provinces of Zuid-Holland, Noord-Brabant and Zeeland have presented the government with the 'The Power of the Delta' implementation programme. The parties have voiced their intention to join forces and collaborate on this issue.

The key to resolving the problems in the Delta is to increase the estuary dynamics. Water systems that have been separated by the Delta project must once again be reunited. This will strengthen the natural water flows of the tides and rivers and once again enable a gradual transition between land and water and between salt water and fresh water. Increased dynamics will also benefit water quality and biological production. This will increase the appeal of the region to housing and recreation. Shipping will also benefit from increased estuary dynamics. If the large differences in water level and the separation between salt and fresh water were to disappear, it would take less time to pass locks or perhaps make them superfluous all together.



The Directorate-General for Water Affairs of the Ministry for Transport, Public Works and Water Management is responsible for policy development for the Delta waters. Rijkswaterstaat (Department of Public Works and Water Management) is responsible for the construction, management and maintenance of the main waterways and for implementing the integral water management of the main waterways.

European legislation is becoming increasingly important to water management. The European Water Framework Directive, the Bird and Habitat Directive and the High

Water Directive require that Dutch waters comply in the short to mid term with concrete objectives in the area of water quality, nature and safety. The Blauwe Delta project will help prepare and support the policy of the Ministry for Transport, Public Works and Water Management in respect of the Delta waters.

This booklet is intended for people involved in policy related to the Delta waters and with implementing the associated measures. It provides an overview of the genesis, the problems that occur, the expected developments and the most important issues and solution strategies for the future.

The main challenges in the southwest Delta are to:

- Guarantee long term protection against flooding from rising sea levels.
- Increase the storage capacity to absorb extreme Rhine and Maas flows.
- Comply with the standards in the Water Framework Directive and the objectives of Natura 2000.
- If possible, combat the reduction in sandbank and salt marsh acreage in the Oosterschelde.
- Limit the risks from contaminated alluvium in the beds of the Haringvliet and Hollands Diep.

- Examine the demand for fresh water from the main water supply for agriculture and drinking water in the light of increasing salination that is a result of climate change, (increasing sea levels and reduced river flows in the summer).
- Take timely measures to prevent delays at the locks.
- Where possible, limit the costs of infrastructure maintenance and in the case of new infrastructure to strive to achieve a combination of functions.





## 2 THE GENESIS OF THE DELTA

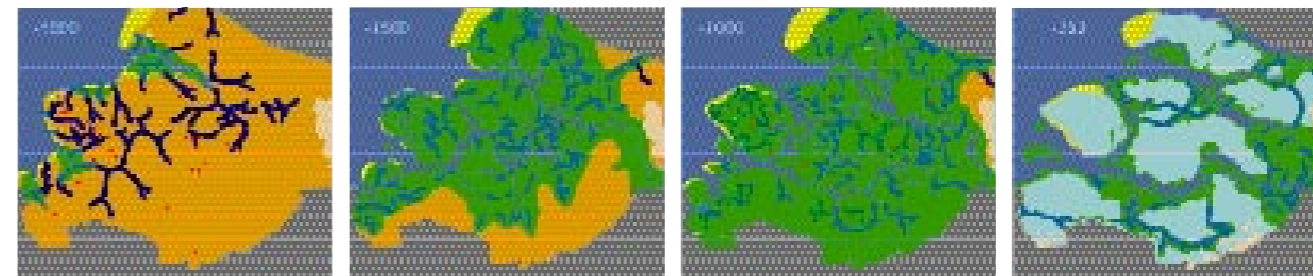
*The last ice age ended ten thousand years ago. The melting ice caps produced the North Sea. Barrier beaches with their dunes and the peat lands behind them came many centuries later. The land to water transition was gradual in the Delta region, as was the mixing of fresh water from the Schelde, Rhine and Maas with the saline seawater.*

The battle against the water started as soon as the first inhabitants had established themselves in the Netherlands. They started living on the high barrier beaches and lived from hunting, fishing and modest amounts of agriculture. The first low dikes appeared along the coast around the tenth century. However, they failed with every serious assault by the water. The dike building meant that surface water could no longer flow directly into the sea. The original solution was to construct outlet sluices. Later it became possible to use windmills to pump out the increasingly deep polders.

Not a century went by without the country being stricken by floods, which frequently resulted in large numbers of victims. Large sections of land disappeared into the sea and this largely determined the contours of the low country. During the St. Elisabeth flood of 1421, which was

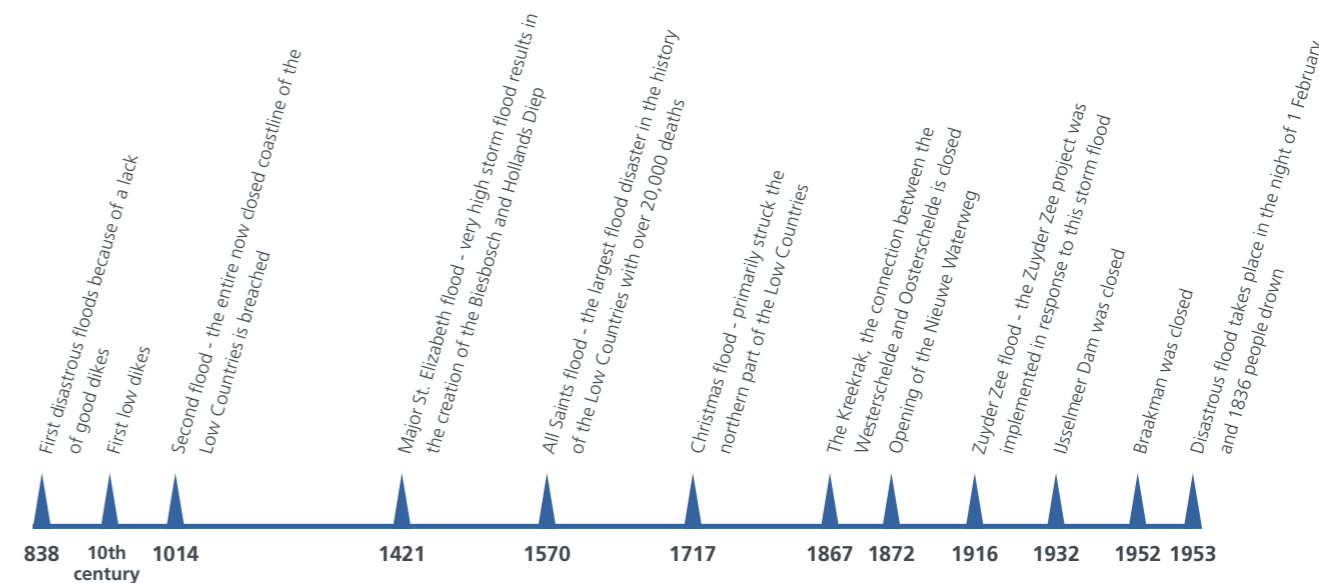
comparable to the disaster of 1953, large sections of the Grote Waard disappeared and the Biesbosch and Hollands Diep were created. The All Saints flood of 1570 swallowed half of Noord-Holland and cost thousands of people their lives. The Verdrongen Land (drowned land) of Saeftinghe in Zeeuws Vlaanderen, the Verdrongen Land (drowned land) of Reimerswaal in Zuid-Beveland and the Verdrongen Zuidland (drowned southern land) in Schouwen-Duiveland are reminders of this. The dikes were made stronger in the nineteenth century through the arrival of new materials, techniques and machinery. Concrete, stone slopes and steam engines became available. But the sea wouldn't be stopped. Another three major floods took place in the twentieth century in 1906, 1916 and 1953.

The dike building and the use of ground outside the dikes gradually pushed back the delta water in the previous centuries until almost only the deeper current channels remained. With time, the shores only accommodated narrow strips of mud flat and salt marsh that were still suitable for land reclamation. This means there is a continually declining amount of space into which water can disperse during storms or during high river levels. As a result, both high water levels and the risk of flooding



the development of the Zeeland region of the Delta (years relative to now) [Source: TNO]

have increased. At the same time, the economic value of the property behind the dikes has increased as a result of increasing population and prosperity. The country and the population have therefore become more vulnerable.



timeline until 1953



### 3 THE NATURAL DELTA

***Before the Delta project, the Rhine, the Schelde and the Brabant rivers flowed unhindered into the sea. The rivers and the sea had free reign of the entire area outside the dikes, which resulted in the development of a varied tidal environment.***

Natural processes controlled the system of estuaries and islands. Fresh river water mixed naturally with the saline seawater and the land gradually gave way to water via a wide coastal zone. Thousands of acres of intertidal area ensured there was a rich diversity of plants and animals. People used this area for fishing and initiated shellfish cultivation in the Oosterschelde.

#### ***Nutrients***

The rivers transported large amounts of nutrients to the Delta. Fresh and salt water mixed together in the natural estuary transition zone, resulting in the conversion of a large portion of the nutrients into food for mankind and animals.

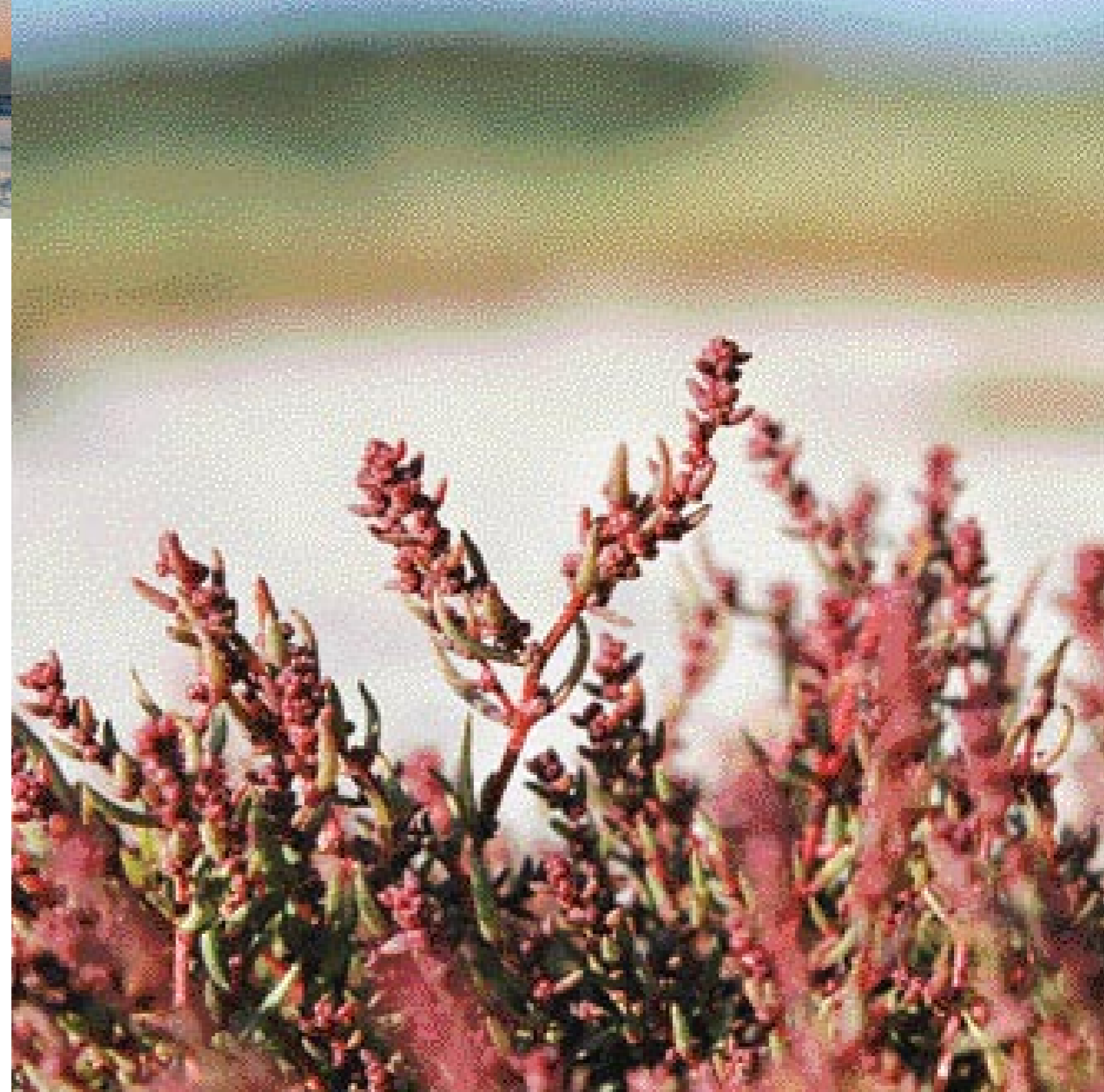
#### ***Tides, rivers and waves in balance***

The tidal and river flows, the waves and the plant growth all help determine the location of the beds and banks in the natural Delta. The tides and the rivers scour out

channels and deposit the sand and silt on the higher areas, such as mud flats and sandbanks. In locations where the mud flats become vegetated, they silt up into high salt marshes and the land grows with the sea. However, waves stir up the sand and silt on mud flats and banks, so a portion will fall back into the channels. Before the Delta project, the power of the tides and the rivers dominated



free outflow of river water into the sea [1950]



the sediment transport (morphodynamics). Consequently, high sandbanks, mud flats and salt marshes could exist beside the deep current channels.

*Estuary dynamics*

In the natural Delta, the water level, the salinity, the water temperature, the nutrients and the tidal flows changed with every season and every location. The plant and animal worlds were equipped for this and formed a varied and robust ecosystem.

The shallow areas in the Delta were nurseries for the fish. Migratory fish migrated unhindered from the sea to the river and back again. The dynamics didn't allow stagnant water, nutrient accumulation or oxygen depletion to occur. It was precisely these changing conditions that are so typical of the estuary tidal landscape and the associated plant and animal worlds.



the drowned land of Saeftinghe

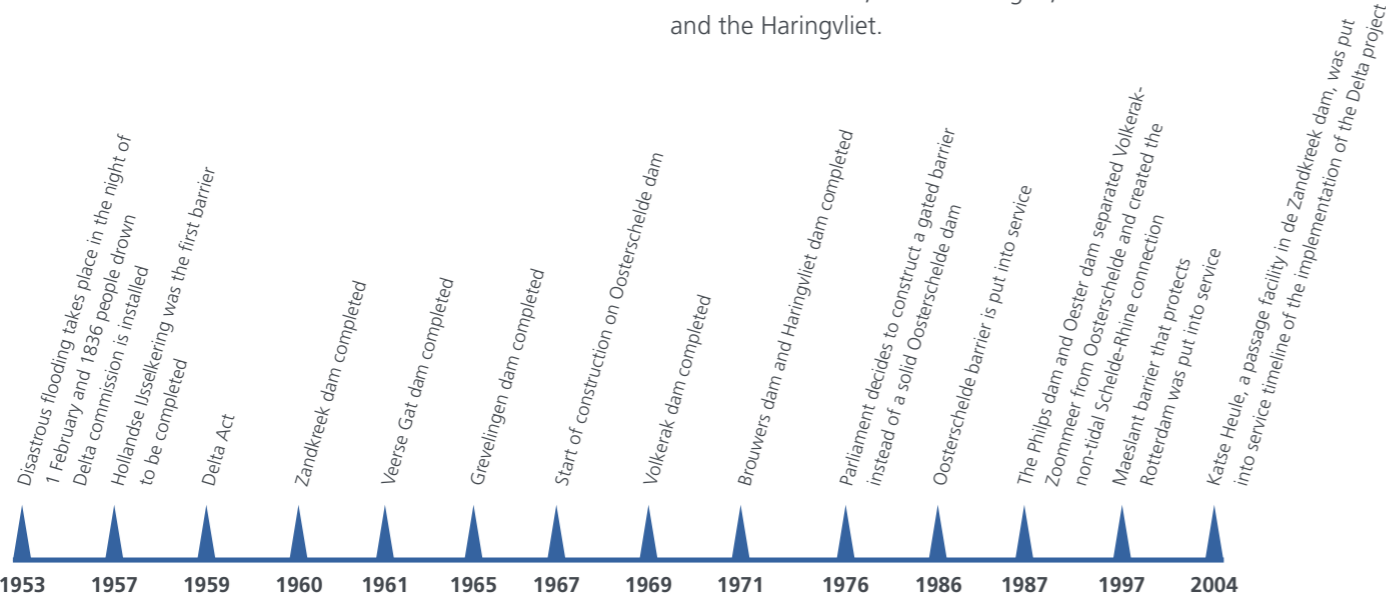




# 4 THE DISASTROUS FLOODS OF 1953 AND THE DELTA PLAN

*On 1 February 1953, a storm flood inundated the Zeeland and Zuid Holland coasts and the low lying westerly part of Noord-Brabant. In the southwest of the Netherlands, cities and villages and 200,000 hectares of fertile ground were submerged. 1836 people did not survive the disaster. 200,000 head of livestock drowned and 72,000 people had to be evacuated.*

In contrast to the past, the flooded land was not abandoned and the recovery started immediately. The dikes were repaired and the polders were pumped out. In the same year, the Delta commission presented a plan to prevent such a disastrous flood from happening again. The Delta plan consisted of shortening the coastline by 700 kilometres by enclosing all or part of the Oosterschelde, the Grevelingen, the Veerse Gat and the Haringvliet.



Timeline of the implementation of the Delta project

The Delta commission felt this was necessary because it would have taken a large amounts of time and money to protect all of the extensive coastline using dikes. Sluices had to be introduced into the Haringvliet to be able to regulate the drainage of river water into the sea. Open sluices enable the rapid drainage of river water during high river flows. The sluices are closed during periods of low river flow to ensure sufficient fresh water will continue to flow through the Nieuwe Waterweg to prevent the salination of the upstream intake points. The Delta commission wishes to keep only the Westerschelde and the Nieuwe Waterweg open to maintain access to the Antwerp and Rotterdam harbours. The Delta plan would not only result in a high level of safety but also provide

other advantages such as better water management, less salination and a better fresh water supply for agriculture. The closed Delta waters provided opportunities for new recreational areas and the connections between the islands were improved and made more reliable.

Ultimately the Delta project resulted in a number of separate fresh, brackish and saline waters, each with its own water level. The Veerse lake and the Grevelingen lake are brackish and saline, respectively. Both lakes have a fixed water level. A number of fresh water systems have also been created, some of which have limited tides (Hollands Diep, Haringvliet, Biesbosch) and one has no tides (Volkerak-Zoommeer). Another two smaller lakes



1953 flood near Sommeldijk



overview of the area that was flooded in 1953  
[Source: [www.deltawerken.com](http://www.deltawerken.com)]

with fixed water levels were also created (brackish Markiezaats lake and fresh Binnenschelde). Making the Hollands Diep, the Haringvliet, the Biesbosch and the Volkerak-Zoommeer into fresh water areas has considerably improved the availability of fresh water in the region.

According to the original plan, the Oosterschelde should also have become a fresh water lake (the Zeeuwse lake). Awareness grew during the progress of the Delta project that this would mean the loss of considerable ecological value as well as the mussel and oyster fisheries. Ultimately,

parliament decided in 1979 to construct a gated storm surge barrier so the tides in the Oosterschelde could largely remain.

The Westerschelde is the last remaining more or less natural estuary in the Delta of the southwest Netherlands. A relatively undisturbed fresh-salt water transition has been preserved here. Because of the shipping, the Nieuwe Waterweg still has an open connection to the North Sea, but this artificial estuary can be closed during a storm by the Maeslant barrier.



the Kreekrak locks



the dams and dikes in the Delta





## 5 THE DELTA AFTER THE DELTA PROJECT

***After the Delta project, safety in the southwest Netherlands improved considerably and the water balance changed drastically. The drawback is that after the construction of the dams, the estuary dynamics reduced considerably and in some cases disappeared entirely. The natural mixing of salt and fresh water, sand, silt and nutrients was banished. The area of salt marshes, mud flats and sandbanks has since been more than halved.***

### ***Nutrients out of balance***

After the construction of the dams, the connection between river and sea has been broken at many locations. The Rhine and Maas water only flows freely to the sea via the Nieuwe Waterweg. During periods of high river flow it is also discharged via the Haringvliet sluices.

The Krammer-Volkerak connection to the southern Delta was cut off by the construction of the Volkerak dam. The nutrient rich water of the Brabant rivers is collected in the Volkerak- Zoom lake and discharged via the Bathse Spui sluice into the Westerschelde. The excessive levels of nutrients and the long period the water remains in this lake results each year in major problems with blooms of blue algae. The death of the algae is accompanied by rotting

and poisonous breakdown products. This result in anoxic water, stench, fish and bird deaths and swimming bans.

The closures have resulted in the other waters in the Delta receiving almost no fresh water, which have therefore become entirely saline. The brackish transition area has become much smaller. Under natural conditions, it is precisely this transition area that processes the huge amount of nutrients from the rivers. This process now only takes place in the Westerschelde. The nutrient-rich river water no longer enters the Grevelingen and Oosterschelde.



salt levels in the Delta waters

Since then, these waters have become nutrient deficient. The Veerse lake has an excess of nutrients because much of the nutrient-rich polder water is no longer discharged. Large amounts of sea lettuce grow here in the summer. Since the culvert Katse Heule was brought into service in the Zandkreek dam, water exchange with the Oosterschelde has increased. As a result, the water quality of the Veerse lake has improved considerably.

### ***Accumulation and contamination***

The currents in this former estuary have reduced considerably since the closure of the Haringvliet. The river silt with the contaminants it contains has since settled to the bottom of the Haringvliet and the Hollands Diep. If the bottom is churned up, this inheritance from the past could once again end up in the water.

### ***Intertidal erosion due to disturbed balance***

The dams have caused large areas to lose, or considerably reduce, the constructive power (accretion and silting) of the tides and river flows. The destructive power (erosion) of the waves is now dominant. Sandbanks and shores and are therefore gradually disappearing into the channels. Shore defences were quickly installed in the non-tidal lakes, to protect the shore, shallow water areas and uncovered sandbanks and salt marshes from crumbling away. The storm surge barrier resulted in a considerable decrease in the tidal volume in the Oosterschelde. As a result, the channels in the Oosterschelde are too big for the amount

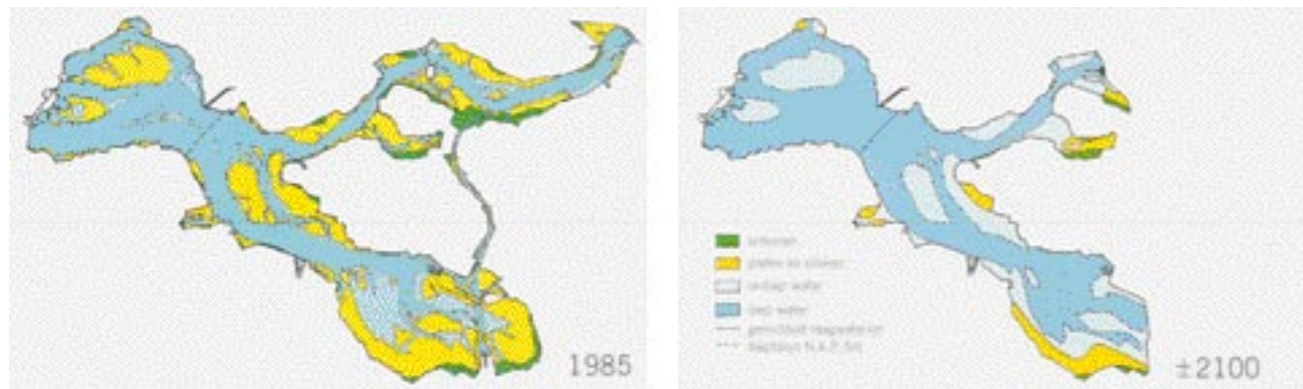
of water that flows through them. Here too, the sandbanks, mud flats and salt marshes are being eroded and the sand and silt is disappearing into the deep and over-sized tidal channels.

### ***Less replacement***

The old deep tidal channels are still present in the lakes. Now the currents have disappeared, the water in the deeper layers is sometimes not replaced for long periods. The cold, more saline water in the bottom layer is heavier than the shallow, warmer water and so they do not mix. This phenomenon is called stratification. Rotting and dead algae can cause an oxygen deficit in the summer, so that a large amount of the biological life at the bottom of these channels can die off.



blue algae in the Volkerak Zoom lake



intertidal erosion due to disturbed balance in the Oosterschelde – the banks, mud flats and salt marshes in 1985 and 2100 [Source: Rijkswaterstaat]

### ***Locks for the shipping sector***

As part of the Delta project, a channel for inland shipping was constructed between Antwerp and Rotterdam: the Schelde-Rhine connection. The connection is non-tidal, but shipping does have to cross a number of water systems, each with their own water level. The ships have to use locks to bridge the differences in water level, and this takes time. Commercial shipping has to pass three major lock complexes between Schelde and Rotterdam and four between the Gent - Terneuzen canal and Rotterdam. The Krammer locks between the Oosterschelde and the Volkerak have an ingenious fresh-salt separation system. As a result, the lock time has increased from 30 to 45 minutes and the management costs are high.

The construction of the Delta project has therefore resulted in different ecological problems and high costs for the management and maintenance of the infrastructure. Strengthening the estuary dynamics could make the Delta more robust and reduce the maintenance.



the lock at Kats





## 6 DEVELOPMENTS IN CLIMATE AND USE

### *Climate change*

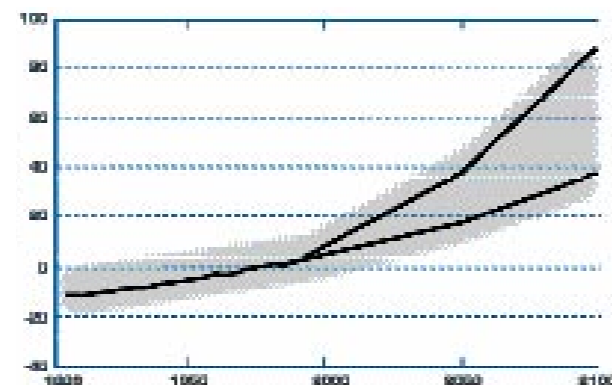
The climate changes related to the greenhouse effect have now been established throughout the world and are also perceptible in our region. The winters are expected to get wetter. The summer will have more frequent hot, dry periods, which will last longer, but there will also be an increased likelihood of short but heavy downpours. The power of storms will probably increase slightly.

### *Increase in sea level*

In the 20<sup>th</sup> century, the sea level increased by approximately 20 centimetres. The warming of the atmosphere will gradually warm up the water in the seas and oceans. This will make the water expand. Land ice masses, such as the glaciers in mountainous areas, Greenland and Antarctica will continue to melt. The expanding seawater and melting land ice will cause the sea level to increase even faster during the coming century by an expected 35 to 85 centimetres. The increase in sea level will mean that lakes with a fixed water level will gradually come to lie a few centimetres below sea level. The risk of flooding near these lakes will increase. It will also become more difficult to replace the water in the lakes because there will be less drainage capacity. This will in turn affect the water quality.

### *Changes to the fresh water supply*

The climate change will cause the river flow to vary more strongly. Periods of extremely high flows, such as those in 1993 and 1995, will be alternated with long periods of extremely low flows in the summer, such as that of 2003. The Delta has little remaining capacity to store high volumes of river flow, now the water can no longer drain away via the Oosterschelde and the Grevelingen. As high river flows coincide with high water levels at sea, this can result in problems in the northern Delta, in particular near Dordrecht and Rotterdam.



increasing sea levels according to the KNMI climate scenario  
(Source: [www.knmi.nl/klimaatscenarios](http://www.knmi.nl/klimaatscenarios))

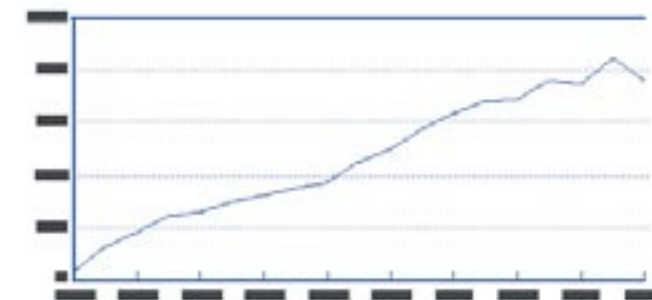
### *Salination*

The increase in sea level and reduced river flows in the summer will enable the saline sea water to penetrate further and more strongly into the Delta. The chloride standard will be exceeded increasingly often at the current intake points. The fresh water supply for agriculture and the drinking water supply may become jeopardised in some areas.

### *Macro-economic developments*

Macro-economic developments are causing strong increases in transportation over water. The number of ships has not increased considerably, but they are getting bigger, both in inland and marine navigation. This means that fewer ships will fit in the lock chamber at one time. To keep the waiting times acceptable, additional lock chambers will eventually be required in the Kreekrak locks, the Krammer locks and the Volkerak locks and an additional sea lock will be required near Terneuzen. Problems will probably be evident at the Kreekrak locks and the Volkerak locks by 2010. The volume of recreational shipping is also increasing.

On busy days, the waiting times at the smaller locks will become longer (Grevelingen lock, Zandkreek lock and Bergse Diep lock). The recreants will require additional connections to the Delta, for example between the Veerse lake and the North Sea and the Grevelingen and the North Sea.



number of containers per year (x1000) at the Kreekrak locks  
(Source: 'Betrouwbaar op de vaarweg', Rijkswaterstaat)

The urban ring around the Delta is continuing to expand, so the need for recreational areas will also increase. An increasing number of people have both the desire and the financial means to live beside the water, with a boat just outside the door. Area development projects are actively searching for opportunities to combine this desire with other wishes, such as renewing the coastal defences and ecological development.

### *European legislation*

The European Water Framework Directive obliges the Netherlands to put all their waters in good chemical and ecological condition. It will become clear in the coming years which measures will have to be used to achieve this. Most Delta waters are also part of the European network of protected nature reserves, Natura 2000.

The Netherlands must specify conservation objectives for these waters and take measures to achieve them. The EU will soon specify the High Water Directive. The objective of this is for member states to jointly map out the flood risks and take measures to limit the consequences of the floods.





## 7 OPERATIONS TO ACHIEVE RICH AND ROBUST DELTA WATERS

***New forms of water management are required in the Delta waters to be able to partially restore its original wealth and robustness. Measures are already being prepared or implemented at a range of locations. European directives have given the search added momentum.***

### ***Protection against flooding***

The increased rate of sea level increase and higher peak flow rates from the Rhine and the Maas can result in higher water levels. Extra attention is therefore required to maintain the protection against flooding.

The hydraulic boundary conditions for water defences are adjusted every five years to take new insights into account. Measures will be necessary if the assessment shows that a water defence structure does not meet these hydraulic boundary conditions. The results of this assessment initiated the Zwakke Schakels (weak links) project in the Delta region, which is designed to strengthen several vulnerable locations along the Zeeland and Zuid-Holland coast. The Zeeweringen (sea defences) project was started to strengthen the stone revetments on the dikes along the Westerschelde and Oosterschelde. If water defences do not comply with the standards, traditional measures are used to make them

wider and higher. This requires a great deal of room and is costly. The ComCoast project is looking for ways of using a wider zone for water defences and if possible to allow these water defences to grow along with the sea level. This is possible by encouraging accretion in front of and behind the water defence structure. Pilot projects have been initiated near Perkpolder and Ellewoutsdijk along the Westerschelde. The objective is to place other functions and activities, such as nature, recreation, homes and aquaculture, in the water defence zone.

The Ruimte voor de Rivier (room for the river) implementing body will work out the details of measures for using the Volkerak-Zoom lake as a water storage area if extreme Rhine and Maas flows should coincide with high water levels at sea.

In the National Administrative Agreement on Water (NBW: Nationaal Bestuursakkoord Water), all the parties involved in water management have drawn up agreements to implement the policy as documented in Water Management in the 21st Century (WB21: Waterbeheer in de 21e eeuw). The national project 'Robuust Hoofdsysteem' (robust main system) is a part of this and has the objective of 'organising' the main water system, which is also called the national



Plan Perkpolder, an example of wide water defence zones [Source: Project ComCoast]

waters. The aim of this is to ensure the risk of flooding from the national waters does not increase in the future.

### ***Ecological wealth***

The water quality in many of the waters leaves something to be desired and some of the beds are contaminated. The estuary dynamics are seriously disrupted. The Water Framework Directive and the Bird and Habitat Directive demand considerable improvements in the short to mid term.

One important condition for the improvement of the water quality and estuary dynamics is the restoration of the connections between the Delta waters. Measures to achieve this are under development for almost all the Delta waters. Some measures are still at the ideas stage while others have already been implemented. A passage facility has been installed in the Zandkreek dam to enable the water in the Veerse lake to be replaced on a more regular basis with water from the Oosterschelde. Recommissioning the siphon in the Grevelingen lake will ensure there is an increased



Area development plan of Perkpolder with a multifunctional coastal zone. Part of the Interreg IIIb North Sea project ComCoast [Combined functions in coastal defence zones]. [Source: Buro Lubbers en Rijnboudt Van der Vossen Rijnboudt for AM en Rabo Vastgoed in cooperation with all the administrative authorities involved.]

exchange with the Oosterschelde. The Haringvliet sluices will soon be left ajar (Haringvlietssluisen op een kier) so migratory fish can swim freely up the river. Connections is also the keyword for the blue algae problem in the Volkerak-Zoom lake. The water quality study (planstudie waterkwaliteit) indicated that at this point the only method to combat the blue algae problem in the mid term is to make the lake saline again. The biggest problem in the Oosterschelde is intertidal erosion.

A study has been initiated into possible solutions. In the Westerschelde, 600 hectares of natural areas will be constructed outside the dikes within the framework of the Ontwikkelings-schets 2010 (2010 development outline). The purpose of this development outline is to safeguard the accessibility, safety and the natural qualities of the Westerschelde. Water quality also continues to demand attention.

Despite these projects, additional measures and projects will be necessary to enable the estuary dynamics to recover

further, so the water quality and the ecology in the Delta waters are able to return to good condition.

#### ***A robust water balance***

The increasing salination of the Delta waters means that solutions are required for the regional fresh water supply for agriculture and drinking water. A broad discussion on water for agriculture was started in 2006 with a pilot study for Tholen and St. Philipsland. After its completion, the discussion will be continued for other areas. A survey of the increasing salination will be carried out for the Rhine-Maas estuary into the problems this causes for users of fresh water and into possible solutions. Another issue is how to make water level management in the Delta lakes more natural and robust. A more natural method of water level management is important to help improve the balance of the power of the tides, rivers and waves. This is essential for the restoration of gradual transitions from land to water. A plan study into water level management was started for the Veerse lake in 2006. A comparable study will be started for the Grevelingen lake in 2007.

#### ***Safe and efficient shipping***

Shipping transportation in the Delta waters is on the increase. This means that waiting times at the large lock complexes will become longer in the coming years. The question is how to prevent this problem. The Netherlands and Flanders will be carrying out a survey into the bottlenecks in the Antwerp-Rotterdam corridor, which also

includes the Kreekrak locks, the Volkerak locks and the Krammer locks. Another investigation will be carried out in cooperation with Flanders to determine whether the accessibility of Gent harbour can be improved by widening the canal and providing an additional lock for ocean shipping. The Schelde estuary will be made safer, more accessible and more natural through the implementation of the Ontwikkelingsschets 2010 (2010 development outline). It may be possible to limit the waiting times for recreational shipping at the yacht locks by changing the operating regimes. If this doesn't result in sufficient improvement, it may be necessary to increase the locking capacity.



artist's impression of the tidal centre in the Brouwers dam  
(Source: Ontwikkelingsschets 'Zicht op de Grevelingen')



### ***Innovative and integral solutions***

The construction and maintenance of infrastructure is expensive. There is a need for a low maintenance, multi-functional solution for safety, water quality and shipping.

Examples of multifunctional solutions include:

- A combination of extra locking capacity at the yacht locks and the construction of passage facilities to enable discharging to take place during high water or to improve the water quality (eg. Bergse Diep lock in the Philips dam).
- Passage facilities for water level management during extremely high water and to improve the water quality.
- A combination of drainage sluices and passage facilities with power generation in hydro-electric power stations (e.g. near the Flakkeese drainage sluice, or and extra drainage sluice in the Brouwers dam).

### ***The challenges for the Delta***

Knowledge about the consequences of the Delta project as well as new insights into the development of the climate, make it possible to design measures for the partial recovery of the estuary dynamics in the Delta region. This will strengthen the natural wealth of the Delta waters and make the area robust for the future.

The challenge for us is to:

- Guarantee long term protection against flooding from rising sea levels.

- Increase the storage capacity to absorb extreme Rhine and Maas flows.
- Comply with the standards in the Water Framework Directive and the objectives of Natura 2000.
- If possible, combat the reduction in sandbank and salt marsh acreage in the Oosterschelde.
- Limit the risks from contaminated sediments in the channel beds of the Haringvliet and Hollands Diep.
- Examine the demand for fresh water from the main water supply for agriculture and drinking water in the light of the increasing salination that is a result of climate change (increasing sea levels and reduced river flows in the summer).
- Take timely measures to prevent delays at the locks.
- Where possible, limit the costs of infrastructure maintenance and in the case of new infrastructure to strive to achieve a combination of functions.

Thanks to the impact of the Delta project, the Netherlands has achieved a leading international position in the area of hydraulic engineering and integrated water management. This can be sustained and expanded in the coming years by working towards a rich and robust Delta. The Dutch partners will combine their strengths in the new national Delta Institute (see [www.deltares.nl](http://www.deltares.nl)) which is currently being set up. International cooperation and exchange are essential to knowledge capital innovation.



# COLOPHON

- Text and composition:** Houtekamer & Van Kleef ([www.hkvk.nl](http://www.hkvk.nl)),  
with cooperation from the Rijkswaterstaat Blauwe Delta project group
- Text editing:** Tekstbureau Met Andere Woorden,  
Arnhem ([www.metanderewoorden.info](http://www.metanderewoorden.info))
- Translation:** Notten Translations, [www.nottentranslations.com](http://www.nottentranslations.com)
- Design:** men@work, Middelburg ([www.menaddwork.nl](http://www.menaddwork.nl))
- Printing:** Drukkerij Herselman
- Cartography:** men@work: pages 12, 17, 18, 20
- Photography:** Petra Rouwendal, Middelburg: cover, pages 3, 6, 10, 13, 31, 33  
Rijkswaterstaat: pages 7, 14, 17, 18, 21, 22, 26 right, 28

November 2007

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